

## **Development and Testing of a Datalogging Device for Physiological Measurements of Deep-diving Odontocetes**

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### **LONG-TERM GOALS**

There is a dire need to determine the normal cardiovascular dive response of deep-diving odontocetes like beaked whales, and to examine how that response might be altered during exposure to anthropogenic sound. However, no one has ever recorded the electrocardiogram of a wild, free-ranging odontocete. Recent advances in the miniaturization of multi-channel datalogging devices now make it possible to conceive of remotely attaching a device to a deep-diving odontocete to record physiological variables such as heart rate and body temperature, which would then permit studies of the cardiovascular response to diving and advance many of the discussions about the susceptibility of beaked whales to gas bubble disease beyond theory and speculation. We will modify our existing technology for making physiological recordings and demonstrate its utility on beaked and pilot whales so that diving physiology studies could be conducted to further our understanding of the susceptibility of these whales to adverse physiological effects of exposure to anthropogenic sounds.

### **OBJECTIVES**

1. Improve on our existing technology for making physiological recordings so that future studies can be conducted to understand susceptibility to adverse effects of exposure to anthropogenic sounds
  - 1.1. Modify our solid-state electrocardiogram (ECG) and dive behavior monitor for use on pilot and beaked whales and other deep diving odontocetes
  - 1.2. Deploy on pilot and/or beaked whales to prove feasibility and collect preliminary data on the physiological response to diving

### **APPROACH**

We plan to make the necessary changes to our current physiological recording device and to conduct test deployments of the device on either pilot or beaked whales. The ECG amplification and filtering circuit we used on our initial pilot whale tests did not produce clear cardiac signals with the close

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electrode spacing that is achievable with a single “T-pole” deployment system. Therefore, we will modify the ECG circuit to increase gain while still attempting to filter out the EMG noise that is likely to be picked up from the muscles in the vicinity of the attachment sites.

We have demonstrated that it is possible to attach an ECG tag using a 2-pole system, but we need additional practice to perfect this technique. We anticipate that with additional field time, we will then be able to successfully attach our modified ECG tag, getting both of the suction cup/electrode darts to firmly attach with sufficient separation, resulting in the recording of a clear ECG.

Encounter rates with short-finned pilot whales off Hawai’i are normally quite high. Short-finned pilot whales are similar in body size to beaked whales, making them a good test surrogate morphologically, and being deep divers they will expose tags to a similar environment of cold, high pressure ocean water. This deep diving behavior of pilot whales means that they also deserve scientific attention to their diving physiology and susceptibility to gas bubble disease. Therefore, we will propose to conduct our test deployments off the island of Hawai’i where we can conduct test deployments on at least two species of beaked whales and short-finned pilot whales.

## WORK COMPLETED

This project provided us with funds to procure three new multi-channel behavioral and physiological recording devices, and to spend three days on the water in Hawaii to attempt deployments of the tags in order to record the electrocardiogram (ECG) of either pilot or beaked whales. We have built three different ECG amplification and filtering circuits to test variations of gain and band-pass filter limits. We have also built one set-up that incorporates a pre-amplifier directly on each electrode that incorporates a very high input impedance and a low output impedance, which we hoped would improve the biopotential signal, which can be degraded due to poor contact between electrode and skin and the movement of the electrode cables. Each archival tag included flotation for when the tag falls off the whale, and sitting on top of each float we have incorporated the usual VHF beacon as well as a very small SPOT5 location-only satellite transmitter. The addition of the satellite tag beacon should drastically improve our odds of finding the tag after it falls off the whale. We conducted tests with our various circuits and determined that the best ECG amplification and filtering circuit combinations were an amplification of either 2500X or 5000X, and a bandpass of 10 – 50 Hz. We worked with Wildlife Computers to obtain a customized Mk10 tag with extra external channels and wired our ECG circuitry to three new tags – two with the 2500X amplifier and one with the 5000X amplifier. The main body of the tag is pictured in Figure 1, where you can see the recording device, flotation, suction-cups containing the primary ECG electrode, VHF beacon, and SPOT5 satellite tag. Figure 2 shows the complete unit with a coiled cable running to the secondary electrode.

## RESULTS

During the three days funded by this grant we were unable to successfully tag and record the ECG with our new monitors. By taking advantage of opportunistically approaching pilot whales during projects funded for tagged whale follow-up or other objectives, we have had an additional three opportunities to attempt to achieve testing of our ECG monitors, but did not succeed. We requested a no-cost-extension for this project for FY13 and used the small amount of remaining funds we had to make improvements to the method of tag deployment so that we are more likely to be successful when attempting to place the ECG datalogging device onto the moving whale. We had hoped to join an on-going field project in the first 9 months of 2013 in order to attempt once more to successfully record the ECG of a freely

diving whale, but no such opportunity became available. Encounter rates with the target species (such as melon-headed whales and false killer whales) for some of these other projects were unusually low in 2013, so that there were no opportunities to spend time with pilot whales for our tag testing.

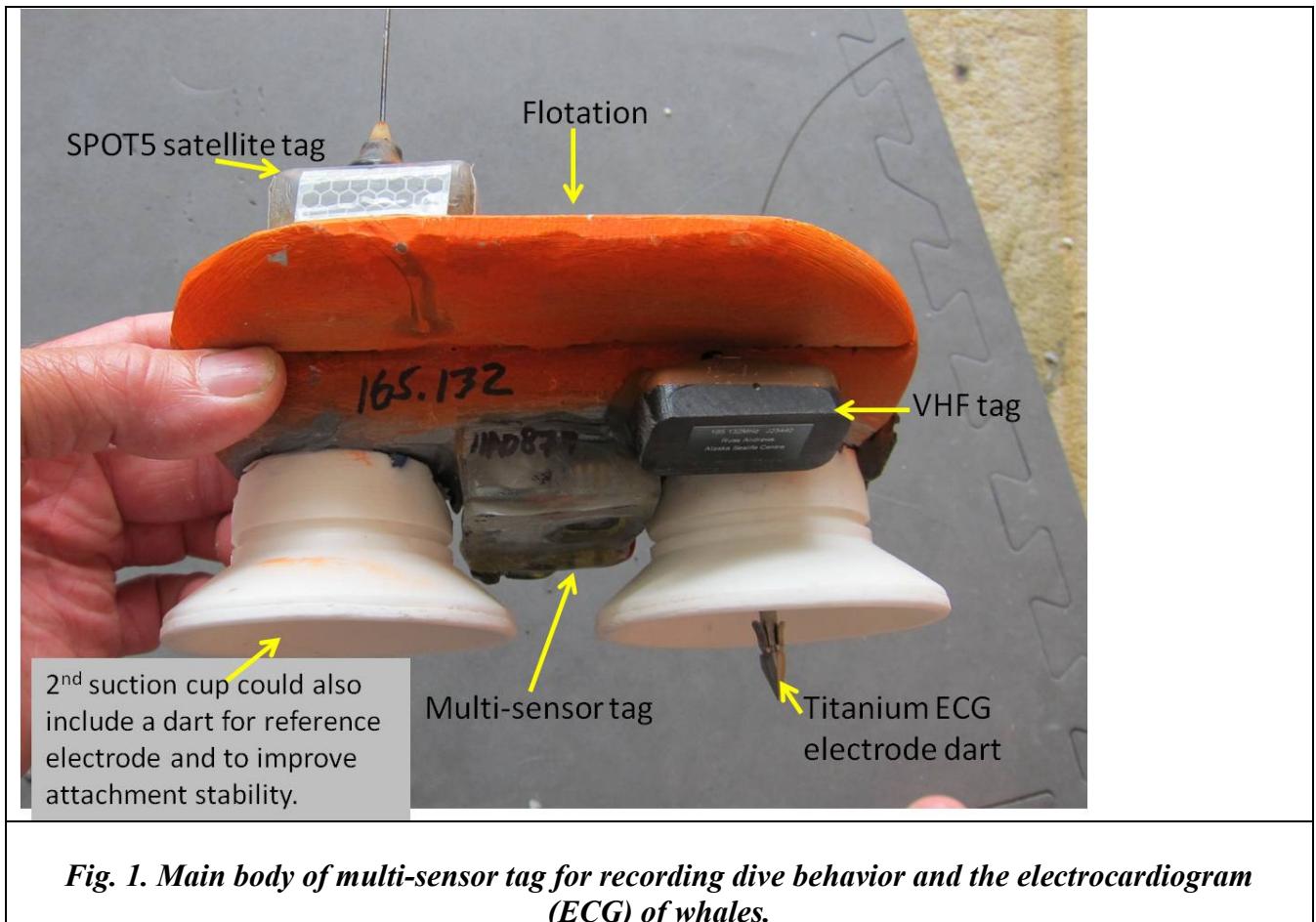
Although we have yet to successfully record the ECG of a freely-diving whale, we have learned a tremendous amount about the challenges involved in this endeavour and have devised many solutions that should bring us closer to being able to achieve our goal. Unanticipated problems with the dataloggers slowed us down, but now that we have a good datalogging system we do not expect any additional troubles on that front. Our biopotential amplifier circuit appears very capable, and so our major challenge is how to apply the complete tag assembly with separated electrodes to a moving whale from a moving boat. With this system it is fairly important that both parts of the tag make contact with the whale simultaneously because even a small reaction by the whale can make it impossible to properly attach the second piece of the tag. Additionally, the curvature of the body of a pilot whale makes it difficult to get a fairly perpendicular attachment when using a long, inflexible pole. Therefore, we have worked to completely modify the electrode dart assemblies and tag body to allow them to attach properly even when they initially touch down at a acute angle relative to the body of the whale. Although we have reached the end of this grant, we still hope to find an opportunity to attempt a deployment by joining other projects studying pilot whales in Hawaii, and therefore to be successful in attaching our tag and recording the ECG during deep diving in pilot whales. Then we can make recommendations on how this task could be accomplished in the future with critical species, such as beaked whales, that are even more difficult to approach and tag.

## IMPACT/APPLICATIONS

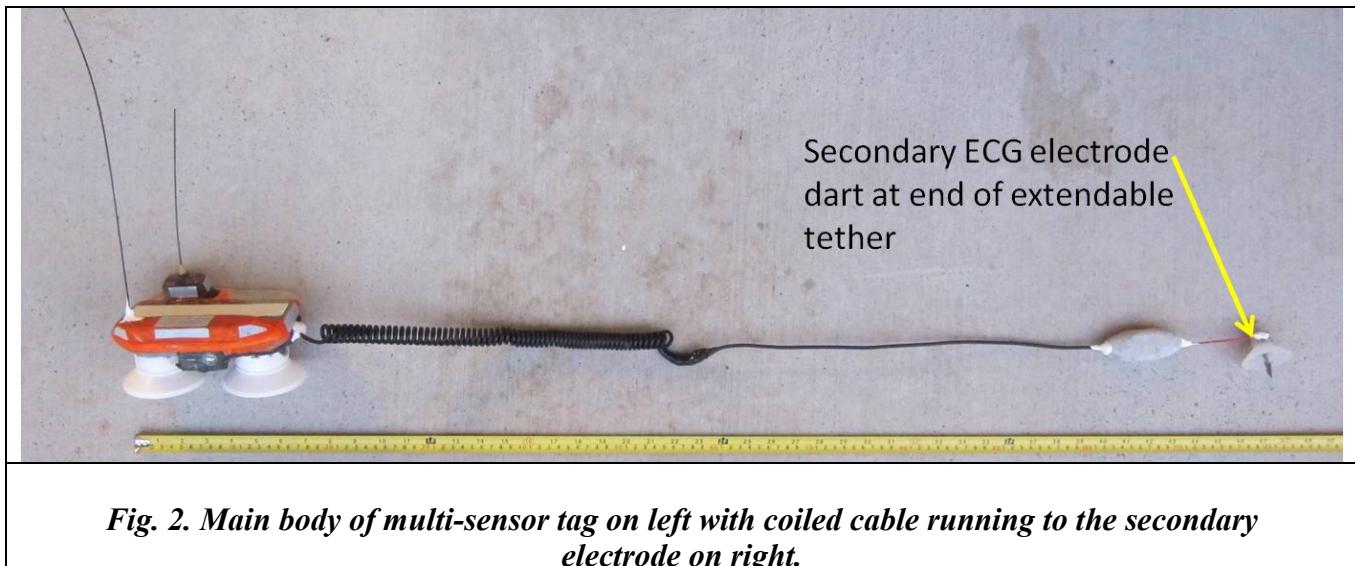
Understanding the potential for impacts of naval activities on protected species of marine mammals and mitigating such impacts requires information on basic physiological and behavioral parameters that are currently a mystery. Demonstration of the successful operation of these physiological recording devices on free-ranging cetaceans will be a breakthrough and should lead to follow-up research on the cardiovascular dive and exercise responses of deep-diving odontocetes. Follow-on studies could include deployments on a sufficient sample size of beaked whales in order to gather the data necessary to adequately understand the physiological mechanisms involved in the potential for gas bubble disease as a consequence of behavioral disturbance in beaked whales.

## RELATED PROJECTS

The National Oceanographic Partnership Program and ONR are supporting our project “Improving attachments of remotely-deployed dorsal fin-mounted tags: tissue structure, hydrodynamics, in situ performance, and tagged-animal follow-up.” The goals of that project are to improve upon our satellite tagging methodology to achieve longer, less variable attachment durations by carefully examining the factors that affect attachment success, along with follow-up studies of whales that have been tagged with a remotely-deployed dorsal fin-mounted tag to accurately quantify wound healing and the effects of tagging on whale survival, reproduction, and behavior. The National Marine Fisheries Service Pacific Islands Fisheries Science Center is supporting research on false killer whale movements in Hawaiian waters, and the Naval Postgraduate School (with funding from N45) is supporting tagging studies of a variety of species in Hawai’i. See: [www.cascadiaresearch.org/hawaii/beakedwhales.htm](http://www.cascadiaresearch.org/hawaii/beakedwhales.htm) and [www.cascadiaresearch.org/hawaii/falsekillerwhale.htm](http://www.cascadiaresearch.org/hawaii/falsekillerwhale.htm) .



**Fig. 1. Main body of multi-sensor tag for recording dive behavior and the electrocardiogram (ECG) of whales.**



**Fig. 2. Main body of multi-sensor tag on left with coiled cable running to the secondary electrode on right.**